<table>
<thead>
<tr>
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<th>Condition Factor, Fat Content and Flavour of Farmed and Wild Salmon</th>
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<tbody>
<tr>
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<td>Schallich, E.; Gormley, T. R. (Thomas Ronan)</td>
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Condition Factor, Fat Content and Flavour of Farmed and Wild Salmon

E. Schallich and T. R. Gormley

Tests on 882 salmon (587 farmed and 295 wild) indicated that the condition factor (CF) is a useful and easily-measured quality index for salmon, especially when combined with data for skin colour and fat content. Wild salmon were better conditioned than farmed, and CF values of >0.90 are desirable for gutted salmon (wild and farmed) and >0.96 and >0.98 for gut-in wild and farmed fish, respectively. Wild salmon had a slightly lower mean fat content than farmed (12.3 vs 12.5%) but showed more variation in fat content. Tests on three spot samples indicated that taste panels were unable to detect a statistically significant flavour difference between farmed and wild salmon. Comprehensive details of the procedures and results are given below.

Background and tests
Large quantities of Atlantic salmon, both farmed and wild are produced/caught in Ireland. While wild salmon are available, fresh, in quantity, for a relatively short period of the year (mostly June-August), the farmed fish are available fresh all year round. As a result, fresh salmon has now become a commodity product with frequent special offers being mounted by supermarkets. The fresh market requires well-conditioned salmon of uniform size while the salmon smoker has the additional requirement of a narrow range in fat content. While most of the fish on offer are of a high quality, some poorly-conditioned fish find their way onto the market; in addition, the wide range in fat content between fish causes problems for smokers. This study addressed both of these aspects in a series of quality tests on farmed and wild fish which included condition factor, visual condition, fish maturity, fat content and taste panel assessment of flavour (spot samples only). Microbiological and spoilage aspects were not considered.

Condition factor (CF)
Salmon deplete their body reserves as they mature sexually and they become thin, i.e. they lose condition. This manifests itself as a loss of tissue fat, an increase in water content, and a paling of the flesh from rich pink/orange to light pink/white. The fish also loses its silver colour and becomes more bronze, and in advanced stages of maturity bronze/red. The condition factor (CF) (see equation 1) is a useful index of condition as it relates fish length to weight. The purpose of these tests was to assess the range in CF values for a large number of salmon and to decide if the CF has application as a quality index at retail level. A CF of 0.75 indicates a very thin fish and a value of 1.25 a very well conditioned salmon. The test is simple, requiring only measuring the length and weight of each fish and entering the data into equation 1.

As farmed salmon are normally delivered to retailers without their gut (-gut), and wild salmon with their gut (+gut), it was necessary to carry out a preliminary test to determine the relationship between the CF of the (+gut) and (-gut) salmon in order to make direct comparisons between farmed and wild. In the test, the CF of 50 farmed salmon was measured on a (+gut) and (-gut) basis; similarly for wild salmon. Regression analysis of the data gave equations 2 and 3.

The fat content of the salmon was measured using a Torry fat meter.
Eqn 1: \( CF = \text{[fish weight (g) x 100]} \div \text{[fish length (cm)]} \)

Eqn 2: \( CF \text{ (farmed) (+gut)} = -0.022 + 1.1184 \text{ CF (-gut)} \)

Eqn 3: \( CF \text{ (wild) (+gut)} = -0.0471 + 1.1219 \text{ CF (-gut)} \)

The correlation coefficients relating to equations 2 and 3 were +0.997 and +0.992, respectively, indicating a strong relationship between CF (+gut) and CF (-gut).

The 50 farmed fish had a higher mean gut content (8.7%) than the wild salmon (7.1%).

**Table 1: Condition factor (CF) for farmed and wild salmon**

<table>
<thead>
<tr>
<th>Samples</th>
<th>Mean CF</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(-gut)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farmed - retail</td>
<td>0.996</td>
<td>0.106</td>
</tr>
<tr>
<td>(set 1) (n=308)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farmed - fish farm</td>
<td>0.972</td>
<td>0.128</td>
</tr>
<tr>
<td>(set 2) (n=279)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wild - retail</td>
<td>1.046²</td>
<td>-</td>
</tr>
<tr>
<td>(set 3) (n=295)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| (+gut)              |         |                    |
| Farmed - retail     | 1.092³  | -                  |
| (set 1) (n=308)     |         |                    |
| Farmed - fish farm  | 1.065³  | -                  |
| (set 2) (n=279)     |         |                    |
| Wild - retail       | 1.169   | 0.093              |
| (set 3) (n=295)     |         |                    |

1Number of salmon tested; ²Calculated from Equation 3; ³Calculated from Equation 2.

**Table 2: Percentage of farmed salmon (+gut) in different condition factor (CF) categories**

<table>
<thead>
<tr>
<th>CF category</th>
<th>Farmed - retail (n=308)</th>
<th>Farmed - fish farm (n=279)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.75</td>
<td>0</td>
<td>2.5</td>
</tr>
<tr>
<td>0.75 - 0.90</td>
<td>14.9</td>
<td>27.2</td>
</tr>
<tr>
<td>0.90 - 1.05</td>
<td>60.1</td>
<td>44.6</td>
</tr>
<tr>
<td>1.05 - 1.20</td>
<td>19.5</td>
<td>20.3</td>
</tr>
<tr>
<td>1.20 - 1.35</td>
<td>5.9</td>
<td>4.3</td>
</tr>
<tr>
<td>1.35 - 1.50</td>
<td>0.6</td>
<td>1.1</td>
</tr>
</tbody>
</table>

1Number of salmon tested.

The farmed fish had the lowest CF value but the highest variation. The spread in the data is shown in Tables 2 and 3 and the largest proportion of farmed fish were on the 0.90 to 1.05 CF category (Table 2) and wild fish in the 1.12 to 1.28 CF category (Table 3). On the basis of these tests it is advocated that the CF (-gut) should be >0.90 for both wild and farmed salmon and the CF (+gut) >0.98 (for farmed) and >0.96 (for wild). These break-points could be used by producers and retailers as indices of 'acceptance/rejection' for individual fish and the results show that 14.9% of the farmed-retail (set 1) fish, 29.7% of the farmed-fish farm (set 2) fish, and 0.6% of the wild salmon (set 3) (see Tables 2 and 3) would be rejected on a CF basis.

The farmed-retail and wild-retail salmon were similar in length and weight (mean values) but the wild fish had the widest variation (Table 4) of these two. The farmed-fish farm samples which were selected to 'cover' a wide range in CF

**Table 3: Percentage of wild salmon (+gut) in different condition factor (CF) categories**

<table>
<thead>
<tr>
<th>CF category</th>
<th>(%) (n=295)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.80</td>
<td>0.3</td>
</tr>
<tr>
<td>0.80 - 0.96</td>
<td>0.3</td>
</tr>
<tr>
<td>0.96 - 1.12</td>
<td>27.1</td>
</tr>
<tr>
<td>1.12 - 1.28</td>
<td>63.1</td>
</tr>
<tr>
<td>1.28 - 1.44</td>
<td>8.6</td>
</tr>
<tr>
<td>&gt;1.44</td>
<td>0.3</td>
</tr>
</tbody>
</table>

1Number of salmon tested.

**Table 4: Mean values for the length and weight of the farmed and wild salmon samples tested**

<table>
<thead>
<tr>
<th>Samples</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (cm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farmed - retail</td>
<td>63.8</td>
<td>3.9</td>
</tr>
<tr>
<td>(n=308)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farmed - fish farm</td>
<td>69.7</td>
<td>6.4</td>
</tr>
<tr>
<td>(n=279)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wild - retail</td>
<td>61.1</td>
<td>4.7</td>
</tr>
<tr>
<td>(n=295)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (g)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farmed - retail</td>
<td>2618</td>
<td>839</td>
</tr>
<tr>
<td>(n=308)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farmed - fish farm</td>
<td>3229</td>
<td>899</td>
</tr>
<tr>
<td>(n=279)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wild - retail</td>
<td>2724</td>
<td>725</td>
</tr>
<tr>
<td>(n=295)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1Number of salmon tested.

Autumn/Winter 1996
TABLE 5: Visual assessment of farmed and wild salmon

<table>
<thead>
<tr>
<th>Factor</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual condition1</td>
<td></td>
</tr>
<tr>
<td>Farmed - retail (n=308)²</td>
<td>+1.21</td>
</tr>
<tr>
<td>Farmed - fish farm (n=279)</td>
<td>+1.26</td>
</tr>
<tr>
<td>Wild - retail (n=295)</td>
<td>+1.17</td>
</tr>
<tr>
<td>Skin colour2</td>
<td></td>
</tr>
<tr>
<td>Farmed - retail (n=308)²</td>
<td>1.39</td>
</tr>
<tr>
<td>Farmed - fish farm (n=279)</td>
<td>1.31</td>
</tr>
<tr>
<td>Wild - retail (n=295)</td>
<td>1.09</td>
</tr>
</tbody>
</table>

¹5-point scale (+2 = very good condition; -2 = very poor condition; 0 = moderate condition.
²Number of salmon tested.
³5-point scale (1 = silver; 2 = slightly yellow/bronze; 3 = yellow/bronze/red).

Visual assessment
The condition of the 882 salmon (sets 1-3) was assessed visually (by a single judge) on a 5-point scale ranging from very well conditioned (+2) to very poorly conditioned (-2). The data (Table 5) contradict the objective CF data in Table 1 in that the wild salmon received a lower mean condition rating than the farmed. This may be due to the fact that, visually, wild fish may appear leaner (i.e. fitter from extensive swimming) than farmed while still achieving a high CF value, i.e. the flesh may be more ‘dense’ (see texture data, Table 8).

Fish maturity was assessed (single judge) by scoring the skin colour of each fish as silver (score = 1), slightly yellow/bronze (score = 2) or yellow/bronze/red (score = 3). The mean data (Table 5) showed that the wild salmon were the most silver. Ideally the skin colour mean value should be less than 1.33 (based on a sample of at least 12 fish) as this allows the ‘inclusion’ of one slightly overmature fish in every three. The results (Table 5) suggest that some of the farmed fish were too mature, as indicated by slight bronzing and loss of silver skin colour, and should have been harvested earlier.

Fat content
Fish oil has a good health image because it contains omega-3 polyunsaturated fatty acids which are reputed to be beneficial for the heart and circulatory system. The fat content of salmon is important, therefore, from a nutritional point of view with minimum values of at least 10% desirable. The fat content is also important for the smoking of salmon, with the ideal range 9-12%.

The fat content of salmon is affected by diet and stage of maturity. The fat content of the 987 salmon in these tests (105 additional salmon were tested for fat content) was measured non-destructively using a Torry fat meter (mean values of 8 readings per fish). The mean data for the three sets of fish (Table 6) were all in excess of 10% and the wild salmon showed the greatest variation in fat content. The spread of the data is presented in Table 7 and the largest percentage of salmon were in the 12-16% category for the farmed retail and wild-retail sets.

Correlation matrix
The variables skin colour, visual condition, length, weight, fat and CF were correlated with each other for the three sample sets. The coefficients were small, thus indicating an inability to predict one variable from another; only four values were >0.70, i.e. weight x length = +0.87, +0.91 and +0.95 for farmed-retail, farmed-fish farm and wild-retail samples respectively, and +0.73 for visual condition x weight for farmed-fish farm samples.

Flavour, colour, texture
Twenty-member taste panels were unable to detect a statistically significant flavour difference between farmed and wild salmon (steamed and served cold) in three separate panels, with responses of 12/8, 11/9 and 12/8 in favour of the farmed samples. A preference ratio of at least 15/5 is required for statistical significance. However, the data do show a non-significant trend in favour of the farmed

TABLE 6: Fat content (%) of farmed and wild salmon

<table>
<thead>
<tr>
<th>Samples</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmed - retail (n=308)¹</td>
<td>12.49</td>
<td>2.52</td>
</tr>
<tr>
<td>Farmed - fish farm (n=384)²</td>
<td>11.50</td>
<td>2.56</td>
</tr>
<tr>
<td>Wild - retail (n=295)</td>
<td>12.25</td>
<td>3.01</td>
</tr>
</tbody>
</table>

¹Number of salmon tested.
²105 additional salmon were tested for fat content.

TABLE 7: Percentage of salmon in different fat categories

<table>
<thead>
<tr>
<th>Fat (%)</th>
<th>Farmed - retail (n=308)¹</th>
<th>Farmed - fish farm (n=384)²</th>
<th>Wild - retail (n=295)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 4</td>
<td>0.3</td>
<td>0.3</td>
<td>0</td>
</tr>
<tr>
<td>4 - 8</td>
<td>4.5</td>
<td>7.6</td>
<td>3.5</td>
</tr>
<tr>
<td>8 - 12</td>
<td>37.7</td>
<td>52.6</td>
<td>36.6</td>
</tr>
<tr>
<td>12 - 16</td>
<td>51.3</td>
<td>38.0</td>
<td>45.4</td>
</tr>
<tr>
<td>16 - 20</td>
<td>6.2</td>
<td>1.6</td>
<td>9.2</td>
</tr>
<tr>
<td>&gt;20</td>
<td>0</td>
<td>0</td>
<td>0.3</td>
</tr>
</tbody>
</table>

¹Number of salmon tested.
samples. The samples were carefully selected for similar fat contents, i.e. 13.6 vs 12.6% (panel 1), 14.8 vs 14.4% (panel 2) and 14.0 vs 14.4% (panel 3) thus eliminating fat as a factor influencing flavour.

Portions from the salmon tasted by the panelists were sheared (100 g of steamed salmon cooled to 15°C; Kramer shear cell) and tested for colour (hue angle; Hunter colour meter). The results (Table 8) show that the wild salmon had a firmer texture but a less pink colour (greater hue angle) than the farmed samples. The difference in texture may be a muscle-tone effect in the wild fish (i.e. more swimming) while the colour difference is a reflection of a higher pigment concentration in the diet of the farmed fish. It is important to stress that these tests were carried out on spot samples and a greater number of samples should be tested for conclusive flavour, texture and colour results.

Conclusions
- The condition factor (CF) of wild salmon was higher than farmed.
- The CF is a useful and easily-measured quality index for salmon, especially when combined with fat content and skin colour, and has application at fish-farm and retail levels.

Equations have been developed to convert CF (+gut) to CF (-gut) and vice-versa in wild and farmed salmon.

- CF (-gut) values of >0.90 are desirable for both wild and farmed salmon; CF (+gut) values should be >0.96 (wild) and >0.98 (farmed).
- Ideally the salmon skin colour mean value should be <1.33 (based on a sample of at least 12 fish) and using a visual scoring system where 1 = silver; 2 = slightly yellow/bronze; and 3 = yellow/bronze/red.
- Wild salmon (12.3%) had a slightly lower mean fat content than farmed (12.5%) but showed more variation in fat content (i.e. coefficient of variation of 24.6 vs 20.7%).
- Taste panels were unable to detect a statistically significant flavour difference between steamed samples of farmed and wild salmon.

Objective tests indicated that steamed wild salmon had a firmer texture than farmed, while the flesh of the farmed fish was more pink/orange than the wild.

Acknowledgements
Thanks are extended to the Marine Institute, Bia Mara, Dunns (Fish and Poultry) Ltd and Superquinn Ltd for their assistance with these tests; also to the EU LEONARDO programme for the award of a grant to Ms. E. Schallich.

Ms. Evelyn Schallich from Hochschule, Bremerhaven, Germany, was a visiting researcher (EU LEONARDO programme) in the Department of Plant and Marine Foods, Teagasc, The National Food Centre, Dunsinea, Castleknock, Dublin 15. Dr. Ronan Gormley is Head of that Department.

Fresh fish is now available from most high quality supermarkets.

TABLE 8: Shear values (kN) and hue angle\(^1\) (\(\Theta\)) colour values for steamed (tested at 15°C) salmon samples

<table>
<thead>
<tr>
<th>Sample</th>
<th>Shear value (kN)</th>
<th>Hue angle(^1) ((\Theta))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farmed</td>
<td>1.53</td>
<td>41</td>
</tr>
<tr>
<td>Wild</td>
<td>1.32</td>
<td>45</td>
</tr>
<tr>
<td>Test 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farmed</td>
<td>1.77</td>
<td>48</td>
</tr>
<tr>
<td>Wild</td>
<td>1.98</td>
<td>52</td>
</tr>
<tr>
<td>Test 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farmed</td>
<td>1.81</td>
<td>49</td>
</tr>
<tr>
<td>Wild</td>
<td>1.91</td>
<td>56</td>
</tr>
</tbody>
</table>

\(^1\)Hunter meter; \(\Theta = \cot^{-1} a/ b\) (redness)/ (yellowness)
Large quantities of Atlantic salmon, both farmed and wild are produced/caught in Ireland. While wild salmon are available, fresh, in quantity, for a relatively short period of the year (mostly June-August), the farmed fish are available fresh all year round. As a result, fresh salmon has now become a commodity product with frequent special offers being mounted by supermarkets. The fresh market requires well-conditioned salmon of uniform size while salmon smokers have the additional requirement of a narrow range in fat content. While most of the fish on offer are of a high quality, some poorly-conditioned fish find their way onto the market; in addition, the wide range in fat content between fish causes problems for smokers. Both of these aspects were addressed in a series of quality tests on 587 farmed and 295 wild salmon carried out at The National Food Centre (Teagasc) by Evelyn Schallich (a visiting researcher from Bremerhaven, Germany) and Ronan Gormley. The tests included condition factor, visual condition, fish maturity, fat content and taste panel assessment of flavour (spot samples only). Microbiological and spoilage aspects were not considered.

**Condition factor (CF)**

Salmon deplete their body reserves as they mature sexually and they become thin, i.e. they lose condition. This manifests itself as a loss of tissue fat, an increase in water content, and a paling of the flesh from rich pink/orange to light pink/white. The fish also loses its silver colour and becomes more bronze, and in advanced stages of maturity bronze/red. The condition factor (CF) is a useful index of condition as it relates fish length to weight. A CF of 0.75 indicates a very thin fish and a value of 1.25 a very well conditioned salmon. The test is simple, requiring only measuring the length and weight of each fish and entering the data into the CF equation i.e.

\[ \text{CF} = \frac{[\text{fish weight (g)} \times 100]}{[\text{fish length (cm)}]^3} \]

Visual assessment was carried out by a single judge and the fat content was measured using a Torry fat meter.
**Results and conclusions**

- The condition factor (CF) of wild salmon was higher than farmed.
- The CF is a useful and easily-measured quality index for salmon, especially when combined with fat content and skin colour, and has application at fish-farm and retail levels.
- Equations have been developed to convert CF (+gut) to CF (-gut) and vice-versa in wild and farmed salmon.
- CF (-gut) values of >0.90 are desirable for both wild and farmed salmon; CF (+gut) values should be >0.96 (wild) and >0.98 (farmed).
- Ideally the salmon skin colour mean value should be <1.33 (based on a sample of at least 12 fish) and using a visual scoring system where 1 = silver; 2 = slightly yellow/bronze; and 3 = yellow/bronze/red.
- Wild salmon (12.3%) had a slightly lower mean fat content than farmed (12.5%) but showed more variation in fat content (i.e. coefficient of variation of 24.6 vs 20.7%).
- Taste panels were unable to detect a statistically significant flavour difference between steamed farmed and wild salmon served cold. Objective tests indicated that steamed wild salmon had a firmer texture than farmed, while the flesh of the farmed fish was more pink/orange than the wild.

*The complete study has been published in Farm and Food, 1996, 6 (3), and a copy can be obtained from Dr Ronan Gormley at Teagasc, The National Food Centre, Dunsinea, Castleknock, Dublin 15. Tel: 01-8383222; Fax: 01-8383684.*